

EarthSaw In-Situ Containment of Pits and Trenches

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Introduction

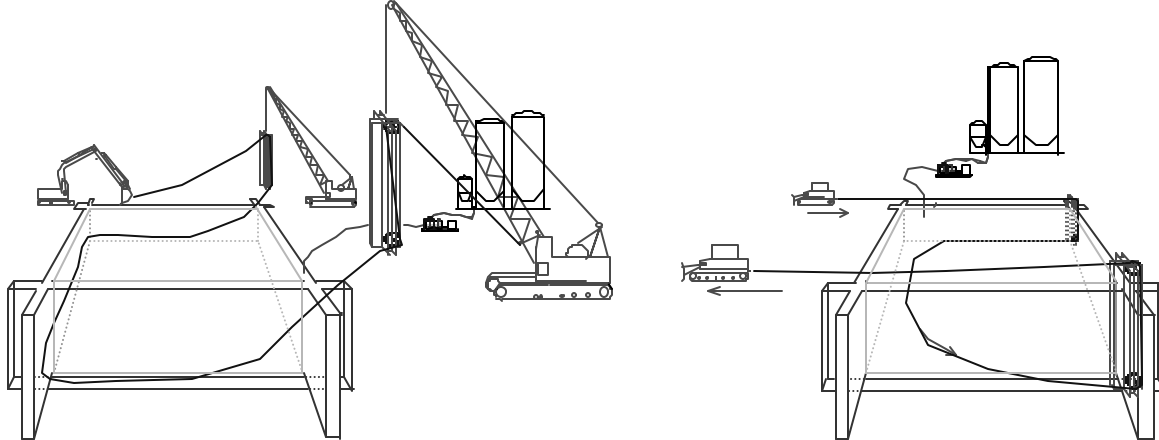
Many government disposal sites which received low level and mixed radioactive waste during the period from the mid nineteen forties to the early nineteen eighties received this waste in unlined pits and trenches. Over 3 million cubic yards of these wastes were buried. Some of this waste now presents an unacceptable environmental risk but for various technical reasons it is exceedingly difficult and costly to safely remove and re-dispose.

In the early nineties, DOE engineers viewing a presentation on jet grouting methods, expressed a wish list for containment technology for creating a bottom barrier under a closed radioactive mixed waste disposal pit. Objectives for the technology were for a method which could work in almost any soil type, including cobbles and even fractured rock, and which could safely isolate a waste site holding undocumented waste. Since the waste could be almost any type of material with any characteristics we concluded that we would be unable to drill through the waste or invade it by any chemical or physical means. It was also determined that for the technology to be acceptable it must initially provide an absolute proof of the continuity of the barrier as well as a means of verifying the continuity of the barrier year by year.

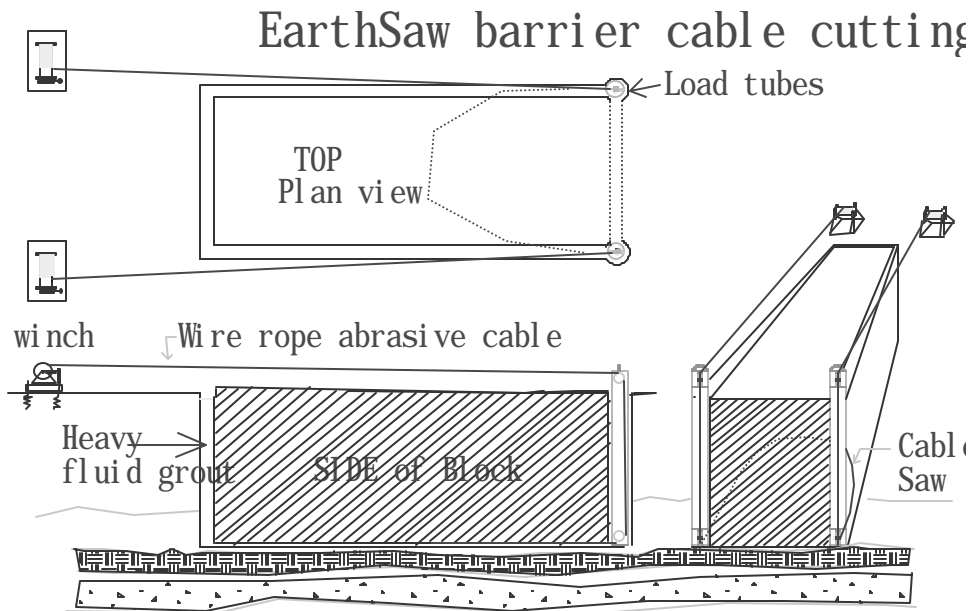
The EarthSaw technique was developed to address these issues. The EarthSaw technology is a method of constructing a high integrity barrier under and around an existing landfill, waste burial site, or underground tank without contacting or exposing any contaminated material. The method works by mechanical cutting of a thin subterranean pathway and then expanding that pathway into a thick impermeable barrier. The cutting work is done by an abrasive steel cable which is circulated or reciprocated through the cut like a band saw. The technology is similar to the diamond wire quarry saw method used to cut large blocks of stone. Cutting of horizontal barriers is made possible by the use of high specific gravity fluid grout which hydraulically supports the overburden material above the horizontal cut. These fluid grouts have special properties which allow them to provide lubricity and cuttings transport while maintaining hydrostatic pressure against a permeable formation. Several types of grout fluids are available. Some harden into a rock-like solid while others remain soft and pliable.

The patented technique can take several different forms. The most basic is the **vertical block method**. This method is preferred for smaller sites of less than 2 acres in size. Consider a hypothetical 200 foot by 600 foot site located in a sand and cobble alluvial

soil adjacent to an inland river contaminated with uranium, arsenic, and mercury. Contamination extends 50 feet deep and the water table is 20 feet below grade.



In this method we begin by constructing a conventional 3 foot wide slurry trench around the perimeter of the site using extended backhoe or clamshell excavation to a depth of 60 feet. However we do not backfill the trench with soil bentonite. Instead, we install a special cable saw device into the perimeter trench. This cable saw uses a load frame device at one or more corners of the perimeter trench to transition the horizontal pull on the cable at the bottom of the trench to a horizontal pull at the surface. The load frame is a heavy steel beam with a top and bottom cable pulley, which fits vertically into the intersection corner of the slurry trench. After the cable saw device is installed, the slurry in the trench is replaced with a special high specific gravity TECT B grout. The grout has a higher specific gravity (21 pounds per gallon) than the block of earth (19 pounds per gallon) to be isolated. The trench is filled to within 6 feet of the surface with the heavy grout leaving approximately 4 feet of light weight (11 pound per gallon) bentonite slurry on top of the grout to keep the top of the trench from collapsing. This provides an effective average density of 19.658 pounds per gallon. (If the entire trench were filled with heavy grout the buoyant force would be too strong and the block could break free before the cable saw finishes the cut.)



The cable saw is then reciprocated and the earth block is undercut. The cable saw may be powered by winches or by dozers. Gravity causes the grout to flow into the horizontal cut and to support the block as it is severed from the earth. After the cut proceeds about downrange the free end of the block will begin to rise several inches. During the cut additional light weight slurry is replaced with grout using the actual rise of the block to gauge how much additional grout is needed. After the entire block is floating free, The rest of the light slurry is removed as additional grout is added to the perimeter trench filling it to within 2 feet of the surface. This causes the block to rise to the desired elevation of 3.7 feet. The thickness of the layer of grout below the block is equal to the rise of the block above the surface.

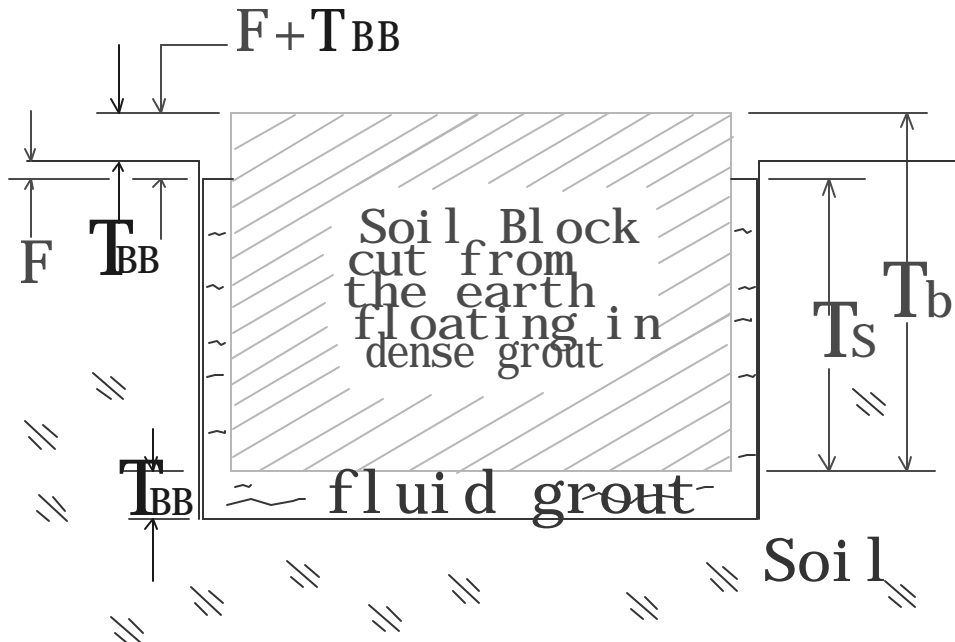
This 200 foot by 600 foot by 60 foot deep example would require over 27,500 cubic yards of grout and contain a volume of 7.2 million cubic yards. Costs for a project of this size are estimated to be nine dollars per cubic yard of volume contained. The largest cost element of the project is for grout materials. Smaller projects would have significantly higher unit costs due to the increased surface area to volume ratio. A 100 foot by 100 foot by 40 foot deep project with the same wall and bottom thickness would use 3,400 cubic yards of grout to contain 400,000 cubic yards and would cost 20 dollars per cubic yard.

The required grout density (D_g) to soil block density (D_b) ratio to achieve proper buoyancy is equal to the ratio of the total vertical thickness of the block of earth (T_b) compared to its submerged depth (T_s). $D_g / D_b = T_b / T_s$

For a given freeboard (F) depth from the surface to the grout level we can calculate the thickness of the resulting bottom barrier (T_{BB}).

$$T_{BB} = T_b - \{(D_b / D_g) \times T_b\} - F$$

If our grout was 21 pounds per gallon and the soil was 19 pounds per gallon and our final Freeboard in the trench was 2 feet the thickness of the bottom barrier under a 60 foot thick soil block would be: $60 \text{ ft} - \{(19/21) \times 60 \text{ ft}\} - 2 \text{ ft} = 3.714 \text{ ft}$ barrier thickness.



T_{BB} , Thickness of the bottom barrier, is equal to the block's increased elevation

$$T_{BB} = T_b - [(D_b / D_g) \times T_b] - F$$

The EarthSaw method is mechanically simple it is likely to be a highly reliable field construction method. It is also considered to be very safe since it does not require personnel to enter potentially contaminated excavations. If mechanical failure should occur when the bottom cut is halfway done, the cable and load frames can be easily removed and replaced and the operation completed without requiring personnel to enter a contaminated area. If the cutting cable breaks we would simply pull out both ends and install a new one. The previously cut area will remain open due to buoyancy, so the new cable may be pulled into position and resume the cut. Since the EarthSaw method uses only a steel cable to span the width and length of the cut it should be adaptable to construct barriers in very large sizes with little or no change in hardware. Also since the barrier is formed as a fluid, it has no seams or joints and is likely to be leak free. The EarthSaw can also make cylindrical containment structures around buried tanks such as those at Hanford or INEEL.

After the barrier is installed an engineered synthetic airtight cap may be installed and keyed into the side walls of the barrier to form a full containment vault. This cap will cover the perimeter trench and prevent drying of the grout near the surface. Extraction wells within the isolated block may be used to remove some or all of the free water

within the vault. Monitoring of residual interior moisture levels against outside levels may be used as a passive monitoring means. For dry sites the barrier may be monitored passively by installing a barometric pressure sensor under the airtight cap and in the surrounding soil outside the barrier. A data logger would collect this information and periodically a report would be made to verify that the internal pressure of the vault did not vary with the day to day barometric pressure changes outside. In some cases it may be useful to circulate dry air through the vault to remove the remaining moisture. After that is complete the integrity could also be monitored by a humidity sensor inside the vault.

The first EarthSaw field demonstration of the vertical block method was carried out in September of 1999 in an industrial park near Houston, Texas. The soil at this site was an unconsolidated river sand which was quite damp below the surface. We performed the method on two adjacent areas. Each test area involved a bedroom sized block of clean earth. The grout slurry is prepared and placed as a viscous liquid with a specific gravity between 2.5 and 3.0 relative to water. Most soil has a bulk specific gravity of 2.0 or less while rocks typically range from 2.5 to the 3.0 value.



In this demonstration we used a novel type of grout, which we call “TECT B”. This grout is made from a highly dispersed clay augmented with non-toxic heavy weight additives. After placement in the ground for many months, TECT B grout undergoes a type of curing process in which it reaches equilibrium with the vapor pressure of water vapor in the ground. The end result of this process is that the TECT B grout develops a plastic consistency similar to stiff peanut butter. Under typical subterranean conditions the grout will never harden and therefore will never have the potential to crack. The product can be tailored to achieve ideal cure at various soil moisture levels. Since this stiff material remains under hydrostatic pressure on the bottom of the barrier it will flow as a liquid and self-heal any displacement caused by earth movement, drilling, or other factors.

When first introduced into the trench, the liquid TECT B grout creates a hydraulic barrier. Even though the grout is in a liquid state it produces an impermeable filter cake on the exposed surfaces of the trench and the horizontal cut as billions of microscopic sheet-like structures stack up on those surfaces. The hydrostatic force of the dense fluid also produces a hydraulic gradient which prevent contaminated water in the soil from passing into the fluid grout. In its liquid form the permeability of the grout starts out in the range of 10^{-6} cm/sec but as curing proceeds it reaches a final permeability of less than 10^{-8} cm/sec. As with conventional vertical slurry walls, Bottom barriers made with TECT B type grout are limited to applications which are not subject to severe subterranean drying conditions. The TECT B soft grout is made from natural materials which are thermodynamically stable in the environment. In a properly designed application where the grout is not exposed to drying conditions, we do not anticipate degradation over time. TECT B grouts can be formulated to adsorb organic liquids as well as aqueous liquids.

More conventional hardening grouts such as TECT A and the molten wax based TECT W malleable grout are also available. These grouts may be used in drying conditions. The TECT A grout hardens in about a month and cures to over 5,000 psi strength. The TECT W wax based grout hardens by cooling but remains deformable down to 40 degrees F. The EarthSaw grouts can also be augmented with a synthetic liner which is pulled into position while the grout is still liquid. Multiple sections of liner may be pulled into position with interlock joints connecting each sheet.

In addition to its properties of crack resistance and low permeability TECT B grout can be formulated to capture or reactively treat certain contaminants. We call this technology "Semi-Permeable Reactive Barriers". Unlike conventional reactive barriers which lose effectiveness within a few years due to permeability reduction and loss of reactive potential, these semi-permeable barriers can last indefinitely. Since the barrier surrounds the source of the contamination no funnel and gate are required and the contaminated groundwater can not go around or under the barrier. This eliminates the need for making the reactive wall (barrier) more permeable than the soil. The barrier may begin as a low permeability material and therefore it may retain its reactive potential for hundreds of years. Reaction products that further reduce permeability only enhance the performance of the barrier.

EarthSaw barriers using the Vertical Block Method described here could be constructed to the same depths as slurry trench technology. Slurry trenching with extended reach backhoes is routinely done to depths of 90 feet or more. Clamshell techniques allow significantly greater depths. It has not been determined what the maximum width and length of single bottom barrier cuts may be. We believe that widths of 200 feet and lengths of 800 feet are feasible in many common soil types. We also believe the method should be applicable both above and below the water table and many kinds of rock.

The EarthSaw is currently being evaluated by NETL in Phase I of a 2 phase program. In phase I we will perform a rigorous engineering analysis to determine the method's potential in different kinds of subterranean conditions and create a computer model of the construction method. We will also prepare all plans and permits to construct a field demonstration in Phase II. In Phase II we will perform a field demonstration on a 50 foot by 50 foot by 30 foot deep area and then evaluate the integrity of the structure.